CASE REPORT

Left fibular hemimelia and congenital femoral deficiency in an 11-year-old patient

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### Patient History

**Length Measurements:**
- 131 mm segmental femoral and tibial difference; foot height difference measured 30 mm; overall femoral head height difference measured 161 mm. Right distal femoral and proximal tibial epiphysiodesis was performed at age 13, resulting in a new overall limb length discrepancy (LLD) of 78 mm.

### Operative Procedure

**Retrograde Femur:**
Venting holes at the osteotomy site were drilled and flexible reaming was performed. A temporary external fixator was applied; distal pins were placed anterior to the reamer shaft and proximal pins were placed just proximal to the end of the nail. An osteotomy was completed and alignment was corrected by intentional angulation and displacement at the osteotomy site. A single blocking screw was placed lateral to the nail to maintain distal femoral alignment.

**Antegrade Tibia:**
Using the same incision, venting holes were drilled and the tibial canal was reamed. A 4.5 mm distal syndesmotic screw was inserted prior to nail insertion to stabilize the tibiotalar joint. The tibial nail was then inserted and a blocking screw was placed posterior to the nail to minimize anterior apex angulation. A temporary extra-articular calcaneotibial screw was placed to prevent equinus contracture and to stabilize the ankle during tibial lengthening.

### Postoperative Results

The femur was lengthened 5 cm and the tibia 2 cm. Lengths are now within normal range. During the consolidation phase and after appropriate regenerate was confirmed under radiography, the patient began short-distance weight bearing. The patient exhibited excellent knee range of motion (ROM).

### Discussion

This patient, at age 11, exhibited dramatic limb length discrepancies as a result of fibular hemimelia and congenital femoral deficiency. By using a remote controlled intramedullary limb lengthening nail (PRECICE®), the risk of surgical complications was reduced and the discomfort associated with external fixation was eliminated. The surgery was successful and both deformity correction and limb lengthening goals were achieved.
CASE REPORT

Retrograde femoral PRECICE<sup>®</sup> intramedullary nail with percutaneous osteoplasty to acutely correct varus deformity and then gradually lengthen the femur in a 14-year-old patient.

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CONDITION
Fracture-Induced Varus Deformity and Resulting Limb Length Discrepancy

PRODUCT
10.7 x 275 mm PRECICE<sup>®</sup> Retrograde Femoral Nail

SURGEON
Scott Nelson, M.D.

Patient History

14-year-old female, presented with the following diagnoses:
Deformity measurements: MAD 41 mm varus/5 mm varus; mLDFA 102/88; and MPTA 88/87
Length Measurements:
Femur 460 mm/484 mm; tibia 382 mm/382 mm; segmental tibial and femoral difference = 24 mm; overall femoral head height difference = 28 mm; no foot height difference or pelvic asymmetry.

Operative Procedure

The patient underwent a limb lengthening procedure of the right leg using a PRECICE intramedullary limb lengthening nail. An entry reamer was used to open the distal canal with a start point medial to the center of the knee for varus correction and a temporary external fixator was applied. A blocking screw was placed on the medial side of the nail just distal to osteoplasty in order to maintain correction of varus deformity and medial displacement. The temporary fixator was then removed and proximal interlocks placed.

Postoperative Results

The patient underwent comprehensive rehabilitation. The patient exhibited good range of motion (ROM) with minimal pain. On follow-up radiographs, the patient exhibited excellent bone regeneration with good alignment.
This patient was playing competitive soccer in 2009, and sustained a fracture to the right distal femoral physis. She developed a varus deformity and shortening of the right lower extremity over the next 3 years. As a result, the segmental tibial and femoral difference at the time of surgery was 24 mm and the overall femoral head height difference was 28 mm.

There are a number of viable surgical options for this patient. Most common is correction of the deformity and lengthening of the right leg with an external fixation device. Dr. Nelson decided against this due to the high rate of complications, patient discomfort, and the patient’s age (14). Other treatment options include: acute correction with plating of the right distal femoral deformity with shortening of the contralateral leg; and acute correction with plating of the right distal femur with concurrent or staged lengthening procedure of the ipsilateral leg, both of which involve patient discomfort issues.

Dr. Nelson instead decided to use a remote-controlled intramedullary limb lengthening nail to reduce surgical complications and enhance patient comfort. The deformity was corrected and leg length equality was achieved.
CASE REPORT

Tibia lengthening with the PRECICE® Limb Lengthening System

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CONDITION
Limb length deficiency (LLD) 7 cm, short femur, ipsilateral total hip replacement (THR) with proximal femur deformity and instability, impending ankle equinus contracture

PRODUCT
10.7 x 305 mm PRECICE® Tibial Nail

SURGEON
Robert Rozbruch, M.D.

Abstract
Case illustrating a 6.5 cm tibial lengthening due to proximal femur related shortening. The presence of a complex hip replacement prosthesis and hip joint instability led to choice of the tibia for lengthening. The PRECICE internal lengthening nail was used and the recovery was excellent. Gastrocsoleus recession was performed to prevent impending ankle equinus contracture.

Brief Clinical History
The patient is a 37-year-old female with a complicated history of hip pathology from childhood. This included femoral head necrosis, fracture, and growth arrest. Ultimately, she was treated with a custom total hip replacement (THR) by a hip specialist who referred the patient for evaluation and treatment of LLD. The THR had problems of instability and was a constrained articulation. The overall LLD was 7 cm and the patient was comfortable wearing a shoe lift for short distances.

Preoperative Clinical Photos and Radiographs
Fig. 1: (a,b) Radiographs showing LLD of 7 cm coming from the femur and hip. Tibia is normal. Note lateral mechanical axis of deviation (MAD).
Fig. 3. A/P pelvis radiograph showing custom-made THR and proximal femur deformity. Note there is a constrained articulation.

Fig. 2. (a–c) Front, side, and back views showing short left lower extremity and a small left hip flexion contracture.

Treatment Strategy
- Avoid lengthening the femur, as it presents the risk of hip dislocation.
- Lengthen tibia and fibula with PRECICE® Nail.
- Perform gastrocsoleus recession since patient is at high risk for developing an equinus contracture of the ankle.

Basic Principles
- It is risky to lengthen the femur when there is hip instability. The proximal femur deformity contributes to this instability. Femur lengthening will increase risk of hip dislocation and displacement of the prosthesis.
- Tibia lengthening minimizes the risk to the hip.
- Tibia lengthening will cause there to be a knee height discrepancy similar to the situation of using a shoe lift. This does not appear to cause a clinical problem when walking.
- Tibia lengthening has a tendency to deform into valgus and procurvatum. At the osteotomy level, if there is space between the nail and the cortex to the concavity of the anticipated deformity, then blocking screw(s) should be inserted. The concavity of valgus deformity is the lateral edge of the bone. The concavity of procurvatum deformity is the posterior edge of the bone.
- The fibula should be stabilized to the tibia at the knee and ankle to prevent distal and proximal migrations respectively.

Fig. 4: Intraoperative fluoroscopy images (a) A/P view after insertion of nail. There does not appear to be space between the lateral border of the nail and the lateral cortex (blue arrow) at the osteotomy level. For this reason, a blocking screw was not inserted. (b) Lateral view after insertion of the nail. There does not appear to be space between the nail and the posterior cortex (orange arrow) at the osteotomy level. For this reason, a blocking screw was not inserted. (c) A syndesmosis screw is inserted to prevent proximal migration of the distal fibula. The oblique screw placement provides superior resistance to a proximal pull on the fibula. (d) Insertion of proximal tibia-fibula screw posterior to the IM nail. The transverse orientation does not provide optimal resistance against the fibula being pulled distally (Fig. 6a). A preferable orientation for this screw is demonstrated by the brown line. (e) The external remote controller (ERC) (stars) is placed over the magnet in the IM nail (red arrow).
Images During Treatment

Fig. 5: (a) Bipedal standing radiograph at end of distraction (70 days after surgery) showing equal leg lengths. Note MAD position relative to preoperative (Fig. 1a). Mild increase in valgus did occur. (b) Front view at 3 months showing equal leg lengths. Note the mark on skin for external remote controller (ERC) placement.

Fig. 6a: Radiographs 3 months after surgery with excellent bone formation. (a) A/P view shows distraction gap of 65 mm and is seen in the rod between the yellow stars. Note the proximal fibula has pulled distally despite the screw (green arrow) (b) Lateral view showing excellent alignment.

Technical Pearls

- Use rotation markers to prevent rotational deformity. Place rotational pins parallel to each other.
- Rotate osteotomy around the intramedullary (IM) nail before insertion of locking screws to assure a complete osteotomy.

Avoiding and Managing Problems

- Avoid propagation of the osteotomy to optimize the angular control of the nail. In this case, the small lateral propagation (Fig. 4a) of the osteotomy led to mild valgus.
- If the canal diameter is greater than the IM nail at the osteotomy site, blocking screws should be inserted to prevent deformity. They work by narrowing the IM canal. Blocking screws are to be inserted in the concavity of the anticipated deformity.
- Mark the location of the magnet in the nail on the skin. The external remote controller must be placed directly over the magnet within the nail to actuate a distraction.
- Pre-drill the osteotomy before reaming. This decreases pressure in the IM canal during reaming and protects against fat embolism syndrome.
- The gastrocsoleus recession helps prevent equinus contracture. Tibia lengthening of greater than 13% and 42 mm are predictors that the patient will need a gastrocsoleus recession for equinus contracture.
- Proximal and distal tibiafibula stabilization is necessary to prevent unwanted fibula migration. Distal migration of the proximal fibula stretches the LCL and the biceps femoris insertion and this can lead to knee flexion contracture. Proximal migration of the distal fibula can lead to ankle deformity, stiffness, and pain. Oblique screw placement provides optimal resistance to fibular migration (Figs. 4c, 4d).
Outcome Clinical Radiographs

**Fig. 7**: (a,b) A/P and lateral radiographs 12 months after surgery. MPTA is 88°.

**Fig. 8**: (a,b) A/P and lateral radiographs 14 months after initial surgery and one week following nail removal.

CASE REPORT

Antegrade femur lengthening with the PRECICE® Limb Lengthening System

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Abstract
This is a case illustrating a 4.5 cm femur lengthening for congenital LLD. The PRECICE internal lengthening nail was used and the recovery was fast with normal unassisted walking at 4 months.

Patient History
The patient is a 25-year-old male with congenital LLD of 4.5 cm and without deformity. No previous treatment was rendered. The patient and the family were not interested in limb lengthening using external fixation at earlier points in his life.

Preoperative Clinical Photos and Radiographs
Fig. 1 (a,b) Front and back view showing left lower extremity shortening of 4.5 cm.

Fig. 2 Preoperative radiographs: (a) Standing radiograph shows LLD of 4.4 cm. MAD is normal. (b) A/P femur showing small IM canal. (c) Lateral femur showing normal anterior bow with apex 15 cm distal to tip of trochanter. (d) Merchant view of knees showing normal patella alignment.
Treatment Strategy

• Femoral lengthening using an intramedullary limb lengthening nail
• Antegrade approach
• Osteotomy at the apex of the femur anterior bow on the lateral radiograph
• Iliotibial band (ITB) tenotomy

Basic Principles

• Osteotomy to be completed at the apex of the anterior bow to allow for a longer, straight nail to be inserted.
• Piriformis or trochanteric entry can be used based on surgeon preference.
• NOTE: Patients less than 19 years of age should have trochanteric entry to avoid avascular necrosis.
• Nail length choice and osteotomy location requires planning. The goal is to have at least 5 cm of thick part of the nail in the distal segment at the end of distraction for optimal stability. During distraction, the thick part of the nail is pulled out of the distal segment.
  • In this case, a 305 mm nail was used. Subtract the starting length of the small diameter telescoping part of the nail (30 mm), the planned lengthening (45 mm), and the minimum length of the thickest part in the distal segment (50 mm).
  • \(305 - (30 + 45 + 50) = 180\) mm
  • The osteotomy must be less than 180 mm from the proximal end of the bone. In this case, 150 mm was chosen without a problem.
  • Reaming 1.5 to 2 mm over the diameter of the nail should be done. In this case, the bone was reamed to 12.5 mm to accommodate a 10.7 mm nail.
  • Although lengthening should ideally be done along the mechanical axis of the femur, when using an IM nail, lengthening is along the anatomic axis. Theoretically, this could increase valgus alignment.
  • In a normally aligned limb, intramedullary lengthening along the anatomical axis of the femur results in a lateral shift of the mechanical axis by approximately 1 mm for each 1 cm of lengthening. In practical terms, this is not a substantial problem. Compare figures 2a to 5a and you will notice no increase in valgus. During lengthening, mild varus of the bone offsets the medialization of the distal femur.

Images During Treatment

Fig. 3: Intraoperative C-arm images (a) Multiple drill holes are made at intended site of osteotomy. (b) Proximal rotational pin is placed posterior to intended path of the nail. A second rotational pin marker is inserted into the distal femur beyond the anticipated end of the nail. Guide wire is inserted into center of trochanter. (c) Cannulated reamer opens path into IM canal. Note the proximal rotation marker. (d) After reaming with flexible reamers 1.5 to 2 mm over the diameter of the IM nail, the solid nail is inserted without guide wire up to the osteotomy site. The osteotomy is then completed with an osteotome. (e) The IM nail is then passed across the osteotomy. (f) The proximal and distal rotational marker pins are used to assure optimal rotational alignment. (g) The external remote controller (ERC) is applied over the magnet in the nail. The skin is marked so that the ERC can be reliably placed for distraction. (h) Distraction gap of 7 mm visible after one week. Note the cloud of new bone already seen.

Fig. 4: (a) Anatomy of the PRECICE® nail on radiograph. (b) Placement of the ERC on the thigh over the magnet in the nail for distraction (see Fig. 3g).
Technical Pearls

- Use rotation markers to prevent rotational deformity. Place rotational pins parallel to each other.
- Correct preoperative rotational deformity (not present in this case) by placing the rotational pins with the amount of angular deformity to be corrected. Use an intraoperative goniometer. After the osteotomy, correct the rotation and make the pins parallel.
- Varus or valgus deformity (not present in this case) can be corrected by performing the osteotomy at the apex of deformity to acutely correct the deformity and then insert nail.
- Rotate osteotomy around the IM nail before insertion of locking screws to assure a complete osteotomy.

Outcome Clinical Photos and Radiographs

![Fig. 5](image-url) Fig. 5: (a) Bipedal standing radiograph at end of distraction (50 days after surgery) showing equal leg lengths. Note MAD position relative to preoperative (Fig. 2a). Increase in valgus did not occur. (b,c) A/P and lateral radiograph of femur 4 months after surgery showing excellent bone healing progression of 4.5 cm regenerated section. Note straightening of the anterior bow of the femur. Note mild varus due to proximal propagation of osteotomy on medial cortex. Full weight bearing was allowed.

Avoiding and Managing Problems

- Avoid propagation of the osteotomy to optimize the angular control of the nail. In this case, the small proximal medial propagation of the osteotomy led to mild varus.
- If the canal diameter is greater than the IM nail at the osteotomy site, blocking screws should be inserted to prevent deformity. They work by narrowing the IM canal. Blocking screws are to be inserted in the concavity of the anticipated deformity.
- Mark the location of the magnet in the nail on the skin. The external magnet controller must be placed directly over the magnet within the nail to actuate a distraction.
- Pre-drill the osteotomy before reaming. This decreases pressure in the IM canal during reaming and protects against fat embolism syndrome.
- The ITB tenotomy helps prevent knee contracture during distraction.
CASE REPORT

Retrograde femoral PRECICE® intramedullary nail combined with a blocking screw to acutely correct the valgus deformity and gradually lengthen the femur in a 15-year-old patient

Frank Schiedel, M.D.
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CONDITION
Perthes disease and resulting limb length discrepancy

PRODUCT
12.5 x 275 mm PRECICE® Retrograde Femoral Nail

SURGEON
Frank Schiedel, M.D.

Patient History

A 15-year-old female (with long leg radiograph shown in Fig. 1) presented with the following diagnosis: Legg-Calve-Perthes disease. Subsequently, there was a varization of the proximal femur leading to an acetabuloplasty and removal of implants one year later. The patient had a limb length discrepancy (LLD) of 3.5 cm due to a closed physis of the proximal tibia and wore a 3 cm shoe lift.

The patient suffered from lower back pain of 5 on a self-estimated visual analog scale (0-10). There was an intermalleolar gap of 10 cm, with femoral caused genu valgum (mLDFA 81°, normal range 85°-90°), and MAD 26 mm. Other observations:
Free range of motion (ROM) in the left knee joint Ex/Flex 0°/130°, reduced ROM in the left hip by Ex/Flex 0°/70°, Out/In 0°/10°, Abd/Add 40°/30°.

Operative Procedure

After the initial analysis of the deformity, the reverse planning method was utilized (as shown in Fig. 2), and the patient underwent a one-step correction of the distal femoral valgus and insertion of a retrograde PRECICE nail for gradual correction. The intramedullary canal was opened with a 3.0 mm K-wire and a cannulated 12.5 mm entry drill. A blocking screw was inserted at the pre-planned lateral position and the osteotomy was performed with an osteotome through a 1 cm skin incision. A ball-tip guide wire was introduced into the canal and reaming was performed in 0.5 mm increments (7.0 - 14 mm). Care was taken to precisely guide the flexible reamers medial to the blocking screw for this one-step correction and lengthening. The blocking screw remained in situ to help prevent the distal femur from falling back into valgus.
Lengthening with the External Remote Controller (ERC) began 7 days post-op: the ERC machine was programmed at 1.0 mm per day and the lengthening goal was 3 cm.

Postoperative Results

Full correction of the axis and LLD was achieved. The affected femur was successfully lengthened 3.0 cm at 37 days post surgery (Fig.3). There were no limb lengthening complications to report and the lengthening protocol remained constant. ROM in the knee joint was Ex/Flex 0°/110° and the patient progressed to full weight bearing 10 weeks following surgery. At 1 year post-op (Fig. 4), the patient demonstrated excellent alignment and full correction of the LLD. The patient no longer complained of lower back or knee pain symptoms at the 1 year post-op visit.
Due to lower back and knee pain, the patient asked for correction of the LLD (shortening due to hip deformity with reduced hip ROM). The valgus deformity of the distal femur also needed to be addressed at the time of surgery. The use of blocking screws can be combined with the PRECICE® limb lengthening system. The patient responded well to the procedure; pain was limited following surgery and she returned to school 10 days postoperatively. One-step correction can be achieved with the use of blocking screws but thorough preoperative planning is mandatory.

CASE REPORT

Acute valgus deformity correction and 4.8 cm tibial lengthening of a 12-year-old female patient with fibular hemimelia

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A 12-year-old female (long leg radiograph shown in Fig. 1) had the following diagnoses: Fibular hemimelia with aplasia Achterman & Kalamchi type II. Patient had four attempted corrections and lengthenings with a hexapod fixator (2004, 2008, 2009, and 2010). A hemiepiphysiodesis for femoral valgus correction was performed in 2012. The patient suffered from knock knees: 29° valgus and a left limb length discrepancy of 4.8 cm (patient was fitted with a 4 cm orthotic). The anticipated LLD at skeletal maturity would be 6.0 cm. The Patient presented with an intermalleolar gap of 12 cm, a tibial-caused genu valgum of MPTA 81° (normal range is 85° – 90°) and MAD 36 mm. Patient exhibited free range of motion (ROM) in the left knee joint (absent cruciate ligaments), slight anterior malalignment (Ex/Flex 0°/150°) and her foot and ankle joint was moderately stiff in 20° of equinus.

Full correction of the axis and limb length discrepancy was achieved (see Fig. 3). The lengthening goal of 4.8 cm was reached 106 days following surgery. There were no ERC or implant related complications and the prescription remained constant. ROM in the knee joint was Ex/Flex 10°/130° and full weight bearing was reached 18 weeks following surgery. ROM in the knee was normalized at 26 weeks and no problems were present at the 1-year follow-up. At the 1-year follow-up, a long leg standing radiograph was taken. Excellent alignment and correction of the desired 4.8 cm was observed, with some remaining leg length discrepancy due to the equinus position of the foot.

Discussion
Despite her young age, the patient was highly experienced in external fixator based lengthening and deformity correction. Guided growth (hemiepiphysiodesis) had led to a corrected femur. For the remaining tibial LLD and deformity, a PRECICE® lengthening procedure was planned. The PRECICE nail is a less invasive solution for acute deformity correction and limb lengthening. The use of blocking screws can be combined with the PRECICE nail to maintain correction and navigate the final position of the nail. A semieextended approach is recommended for patients with deep patellar positioning and for ease of nail insertion.
References and Suggested Reading


Notes
The PRECICE® Intramedullary Limb Lengthening (IMLL) System is composed of an implantable intramedullary nail, locking screws, reusable instruments, and a hand-held External Remote Controller (ERC). The PRECICE nail is a sterile single use device that is surgically implanted using the instruments and locking screws. The ERC is used daily after implantation to non-invasively lengthen or shorten the implant to a prescribed length. The PRECICE System is intended for limb lengthening of the femur and tibia. Contraindications include infection or pathologic conditions of bone such as osteopenia which would impair the ability to securely fix the device, metal allergies and sensitivities, patients whose distance from the surface of the treated limb to the intramedullary canal is greater than 51 mm for the 10.7 and 12.5 mm diameter implants or greater than 38 mm for the 8.5 mm diameter implant, patients with an irregular bone diameter that would prevent insertion of the PRECICE nail, patients in which the PRECICE nail would cross joint spaces or open epiphyseal growth plates, patients in which there is an obliterated medullary canal or other conditions that tend to retard healing such as blood supply limitations, peripheral vascular disease or evidence of inadequate vascularity, patients unwilling or incapable of following postoperative care instructions, patients weighing in excess of 114 kg for the 10.7 and 12.5 mm diameter implants for models H, J, K, and U or weighing in excess of 57 kg for the 8.5 and 10.7 mm diameter implants for models N, M, P, and Q.

The implantable device is only to be used by a trained licensed physician. Please refer to the PRECICE IMLL System instructions for use for complete Important Safety Information. Caution: Federal law restricts this device to sale by or on the order of a physician.